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ON THE POSSIBILITY OF FORECASTING THE APPROXIMATE WINTER RAINFALL FOR NORTHERN VICTORIA,

BY

E. T. QUAYLE, B.A.,

ASSISTANT, COMMONWEALTH METEOROLOGICAL BUREAU, MELBOURNE.

BULLETIN No. 5.

(ISSUED MARCH, 1910.)

Published with the Authority of the Minister of Home Affairs.

H. A. HUNT,
COMMONWEALTH METEOROLOGIST.

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LETTER OF TRANSMITTAL.

Commonwealth of Australia,
Department of Home Affairs,
Meteorological Bureau,
Central Office,
Melbourne, 22nd November, 1909.

Sir,

I beg to submit the following paper by Mr. Quayle for publication.

His deduction curves showing the relation of winter rains to the preceding number of summer monsoonal depressions are in remarkable agreement, but, as in all efforts at the solution of seasonal forecasting, there are some tantalizing exceptions, the most noticeable being in the seasons of 1901, 1906, and 1907.

A somewhat similar treatment of data was made of the South Australian seasons in the year 1896, under the direction of Sir Charles Todd, but the results were, more or less, negative. The investigations herewith carried out by Mr. Quayle for the State of Victoria are more encouraging, and I have requested him to apply his system of treatment to the back records of all the eastern States to determine whether or not there exists a somewhat similar relation between the number of monsoonal depressions and rains of the following winter to other parts of Australia.

The period over which Mr. Quayle has extended his observations is limited to 22 years, as prior to the year 1888 no daily isobaric charts were compiled. This period, it is held, is too short on which to definitely establish a law. It may be that the seeming agreement between the two curves extending from 1888 to 1900 indicates the existence of a law, during which period it would have been possible to anticipate the coming season, in which case a valuable addition will have been added to our knowledge of Meteorology. Unfortunately, in the succeeding years the curves do not present the guiding features of those preceding them, which set may be only a coincidence, and whether it establishes a law can only be settled by future history.

I am hopeful that Mr. Quayle has established a tentative basis for seasonal forecasting, but I should be more hopeful if the contradictory evidence had occurred during the early years his investigations cover, rather than during the latter series, for the reason that in the early days of Australian Meteorology, the data was neither as accurate nor as complete as during the more recent years.

I have the honour to be,
Sir,
Your obedient Servant,
H. A. HUNT,
Commonwealth Meteorologist.

The Secretary,
Department of Home Affairs.

V.5 cont.

Submitted for approval.
DAVID MILLER,
Secretary, Department of Home Affairs.

Div. 9

Approved.
G. W. FULLER,
Minister of State for Home Affairs.

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ON THE POSSIBILITY OF FORECASTING THE APPROXIMATE WINTER RAINFALL FOR NORTHERN VICTORIA.

BY E. T. QUAYLE, B.A., ASSISTANT.

Commonwealth Meteorological Bureau,
Melbourne.

In considering the possibility of evolving rules for seasonal forecasts, it has long been the writer's conviction that ordinary statistical methods must prove inadequate. They do not enable the essential differences between the weather of successive years to be grasped. Discussing seasonal differences by means of the ordinary barometer and temperature averages, variations, &c., seems like fighting at long range. Close contact is required for decisive results. Summaries and averages as ordinarily prepared are a necessity for climatic studies, but only faintly hint at weather peculiarities, and must almost inevitably hide much of what gives to each season its individuality.

In the case of the barometer it seems probable that its great value for the issue of daily forecasts has disposed us too much to look to its averages, especially when these cover lengthy periods and show periodic variations, as guides to seasonal forecasts. It is, of course, not intended to suggest that very important results may not be obtained from such studies, since it is certain that in some localities, at all events, cyclical changes in rainfall correspond with cyclical changes in air pressure, but the results so far obtained by this method are too general for practical use.

No one who has done much forecasting by means of the daily weather chart can have altogether escaped the conviction that there is something in the behaviour of the weather in any given season which differentiates it from other seasons and for which some allowance must be made if the forecasts are to have the maximum accuracy. Though the succession of high and low barometer readings in corresponding months may be similar, the resulting rains may be very different. A remark made in a weather diary for November, 1903, may help to illustrate another difference not easily seen by looking at ordinary statistical summaries—" The progress of storm systems this season is very different from that of corresponding types in 1901. Then the following ' high ' generally pressed along the South coast in such a way as to cut monsoonal ' lows ' (troughs) in two, one half going East over New South Wales and Queensland, and the other moving South-east towards New Zealand as an ordinary Antarctic. This year monsoonal storms maintain their character."

The Southern parts of Australia in summer are almost on the Equatorial side of the subtropical high pressure belt, but in winter on the Polar side. The result is that in summer our rain bearing storms frequently appear to be of tropical, or, as we term it, of " monsoonal " origin, and in winter are more directly connected with the Eastward drift of the great cyclonic depressions, the tracks of whose centres lie generally in higher latitudes. But there are great variations from this arrangement, summer types appearing in winter and winter types in summer, as well as eccentricities innumerable of cyclonic growth and decay. Now the use of barometric averages alone will not make it clear to what extent Melbourne, say, was on the Northern or Southern side of the various moving high pressure systems, but to know the weather this is a vital consideration. Again, periods of low barometric pressure over Southern Australia may be due to very different modes of atmospheric circulation, and may not infrequently be associated with monsoonal influences and gentle gradients instead of the more usual accompaniment of energetic " Antarctics." It is evident that only analyses of barometric variations having especial regard to space as well as time will enable essentials like these to be realized. That a mean barometric pressure above or below normal should correspond to deficient or excess rainfall is what one would expect when a sufficiently long period is considered, but the rule is by no means invariable. For instance, both the pressure and rainfall over Northern Victoria during the summer halves of 1888, 1889, 1891, 1895, and 1904 were well above average.

Similar difficulties become apparent when dealing with temperatures, since practically the same methods of treatment are adopted for both, and one is to a certain extent dependent upon the other, as in the obvious relation between temperatures and wind directions. Local peculiarities of pressure distribution maintained pretty consistently for a month or two, as over South eastern Australia in February, 1898, may give quite abnormal local results without indicating any real change in the general store of atmospheric heat. We must not only know whether the mean temperatures were above or below normal, but in considerable detail why they were so and have some means of classifying this detailed information. In short, the chief difference between dry and wet years, apart from the actual difference in rainfall, should be sought, not so much in comparisons of the ordinary statistical summaries of air pressure, temperature, &c., but in some way of expressing the differing modes of storm and rain production under the operation of the sun's heat upon an atmosphere charged to a variable extent with aqueous vapour.

With this end in view the writer began some years ago to classify all storm systems as they affected Victoria. These fall naturally into two main divisions—(1) those whose circulation is controlled from centres lying over Southern waters and usually termed " Antarctic," (2) those which develop within or pass over the continental interior, being in many cases of tropical origin and known as " Monsoonal " disturbances.

The former were subdivided into (*a*) Antarctics, a term intended to cover all storms the centres of which as they pass Victoria lie too far South to be identified, or indicated by closed isobars, (*b*) Antarctic cyclones, storms which, apparently originating in or developing from ordinary Antarctics, show definite centres of low pressure passing either inland or over Bass Strait with a complete wind and cloud circulation.

Monsoonal disturbances were subdivided into—

(*a*) Monsoonal troughs,—depressions which are shown isobarically as simple valleys, generally lying North and South between two high systems and practically open North and South, but uncontrolled as regards wind and clouds by any disturbance centered over the ocean to Southwards.

(*b*) Monsoonal Dips,—trough-like depressions definitely closed to southwards by a high pressure system, or shown only as simple Southward dips of the isobars on the northern side of a high pressure system.

(*c*) Monsoonal cyclones,—depressions originating in either of the preceding and becoming definitely cyclonic in circulation and isobaric contour as they pass over South-eastern Australia.

It might have been anticipated that there would often be considerable difficulty in distinguishing between "Antarctic" and "Monsoonal" controls, but this was very rarely the case, the cloud and especially the wind movements differing to such a marked extent in the two cases that the control could almost always be determined satisfactorily even without any reference to the isobars. It may not be out of place to mention some characteristic differences. The passage of a monsoonal trough over Melbourne is accompanied in most cases by a sudden and complete change of wind from some northerly point to a southerly one, often followed during the next few hours by a slight easterly tendency. During this time all except the lowest types of cloud remain unaffected, or may even become more northerly in direction. The wind velocities, moreover, show no tendency to increase until the trough is about Gabo Island or the extreme south-east corner of the continent, when the control may become oceanic with a decided steepening of barometric gradients to eastwards. When an "Antarctic" passes the first wind change is rarely so complete, or if it is, the direction quickly becomes south-west or even westerly, while squally and often strong winds blow along the coast. The clouds veer westerly, the lowest forms most rapidly, and the upper cirriform portion of the cloud mass, which is the last to be affected, terminates in a clean cut edge lying generally north-west and south-east. This line probably marks the western limit of ascending air at high level.

As monsoonal depressions are generally slow moving, it is not uncommon for one to end its career by absorption into the front of an "Antarctic" disturbance. The local signs of this will, of course, be dependent upon the position of the monsoonal depression when overtaken.

Great care was taken to make the system of classification uniform. For instance, any storm was called Antarctic regardless of previous history, if when passing Victoria its circulation was governed by a centre which had developed over the ocean to southward. That is, the term would be applied to storms entering West Australia or South Australia from the west or north-west, and there definitely cyclonic, if, as was generally the case, the centre of energy was transferred to Southern waters before affecting Victoria.

The charts used were those compiled at the Melbourne Observatory. These are, unfortunately, only available as a tolerably complete series since March, 1887. Most of November of that year is missing, but, as the writer's weather diary of that year contained a full set of copies made from those then appearing in the *Argus* newspaper, it was possible to complete the series fairly well from 1887 onwards.

By the use of these charts then and the occasional aid of local weather observations the number of occurrences of each type of disturbance as described above was taken out for each month, also the number of anticyclones, together with the extreme pressures recorded during the passage of each low or high pressure system over Victoria, and the extremes reached during the month. The mean air pressure, temperature, and total rainfall for Melbourne were also taken out. (In this discussion, however, those figures have been used only so far as they were required to determine types, variations in intensity not being considered).

As the writer's desire was more particularly to study the seasons inland, also because the Northern districts receive the bulk of their rains from fewer and more definite types than southern and coastal districts, chiefly from monsoonal depressions or the fronts of well-developed Antarctics—the monthly rainfall for the Northern Victorian wheat districts was used in place of that for Melbourne. As typical of the northern areas and having sufficiently long records, the following stations were selected:—Swan Hill, Echuca, Yarrawonga, Warracknabeal, Charlton, Bendigo, Shepparton, Dookie, Horsham, and St. Arnaud. The mean for these ten probably represents fairly well the rainfall over about 28,000 square miles of country where the conditions governing rainfall are very similar.

As the winter rains for this area are of supreme importance and those for the summer only a secondary consideration, it seemed reasonable to divide the year into two, the summer half extending from 1st November to 30th April, and the winter from 1st May to 31st October. The results obtained were then summarized as follows:—For each half year the low and high pressure systems passing Victoria were counted and alongside the numbers thus obtained were placed the figures for the rainfall over the northern areas and the mean air pressure and temperature for Melbourne.

Taking now the records in tolerable completeness, namely, those for the 22 years 1888 to 1909 inclusive, a notable deficiency in the number of Monsoonal "Dips" is apparent in the summer halves of what were regarded as bad years, or years of deficient winter rains. This is also true of the other monsoonal types, though not quite to the same extent. For the sake of getting sufficient numbers to reason from it was decided to sum all the monsoonal types for each half-year. This gave an average number for any one summer half-year for the 20 years, 1889–1908, of 11.3. It came somewhat as a surprise to find that when monsoonal depressions are above average frequency the summer rainfall over this area is more often below than above the average, and *vice versâ*, to the extent of fifteen cases out of twenty-two. When compared, however, with the following winter rains an excess in the number of summer monsoonal disturbances is seen to be followed in a large majority of instances by an excess in the winter rainfall. This is so seventeen times out of twenty-two.

To test the reality of the latter relation, the departures from average were plotted for both the summer monsoonal depressions and the following winter rains. Two curves were obtained bearing a very striking resemblance to each other, but, as might have been expected, the rain curve was rather more erratic. The general trend of each seemed, however, almost identical. (It happens for Northern Victoria that the average number of summer monsoonal disturbances, 11.3, is practically the same as the following winter rainfall in inches, 11.2.)

Examining now in the same way the mean air pressures and temperatures at Melbourne, it was found that a pressure below the average (29.900 in.) was followed by winter rains above the average (11.2 in.) fourteen times, and the reverse in eight, and a summer temperature above average (63.1) by winter rains above average, also fourteen times and the reverse in eight. It would thus seem that low mean pressures and high mean temperatures during the summer months are more likely than not to be followed by winter rains above average. The results taken singly do not indicate a high degree of probability and might easily be due to chance, but, as one would naturally regard low pressures and high temperatures as indicating rainy tendencies, it is probable that some weight should be given to these in any attempt to issue a seasonal forecast. This is supported by the experience in South Australia, where it has already been noted by Sir Charles Todd, that high temperatures and low pressures occurring together in summer are usually followed by a wet winter and *vice versâ*. In the 22 years covered by this investigation there are fourteen cases in which the temperature and pressure departures from normal are opposite in sign; of these, ten are in agreement with the rule, and four against it.

In order to evolve a rough rule for predicting the approximate winter rainfall over Northern Victoria, the following simple method was adopted:—The data, as previously indicated, are the number of monsoonal disturbances, the mean pressure and mean temperature for the preceding summer. As it is assumed in this paper that the true seasonal characteristics are best expressed in terms of storm development, and also because the evidence appears to justify it, double weight is given to the monsoonal depressions as compared with pressure and temperature, which may be taken as of equal value for forecasting purposes. The mean departures from the normal are for the pressure ± .023 inches, for the temperature ± 0°.9, and for the number of monsoonal depressions + 2.6. If, now, to the figures for the monsoonal departures we add those for the pressure in hundredths of an inch, multiplied by − 0.6, and those for temperature multiplied by + 1.4, we get combined results with + or − sign, which are a considerable modification of those for the monsoonal departures, naturally tending to numerical exaggeration when all are in agreement. The factors used for the pressure and temperature departures are the multipliers necessary to make them equal the mean monsoonal departures, but divided by 2 on account of the weights.

Noting coincidences of sign only as sufficient for the present, it is seen that the signs of the numbers obtained in this way are in agreement with those for the departures from normal of the following winter rains no less than nineteen times out of twenty-two and in serious disagreement only twice.

This constitutes a very striking series of coincidences which, extending as it does over 22 years, can hardly be considered as due to chance, more especially when the general similarity between the summer monsoonal and winter rain curves is noted. At all events, these results point to the possibility of issuing a winter forecast for Northern Victoria, and this may be done at latest by the end of April in each year, and often by the beginning of that month. Time has not been found yet to extend the investigation to the other States, but, as the southern parts of New South Wales[*] and a good portion of South Australia receive their winter rains under similar conditions, the forecast might, with nearly the same degree of confidence, be extended to them.

TABLE I.

November to April.								May to October.
Year.	Monsoonal.			Total Monsoonal Depressions.	Mean Barometric pressure.	Mean temperature.	Rain.	Rain.
	Troughs.	Dips.	Cyclones.					
					in.		in.	in.
1888..	3	1	2	6	29.966	62.2	9.27	7.90
1889..	5	3	3	11	.933	64.65	9.81	15.42
1890..	9	2	3	14	.918	65.7	7.18	14.26
1891..	3	4	3	10	.940	62.1	9.58	10.21
1892..	6	5	3	14	.902	62.8	4.99	13.58
1893..	11	1	3	15	.857	63.1	5.60	14.70
1894..	8	6	1	15	.882	63.95	7.39	15.89
1895..	7	1	2	10	.940	64.5	8.99	7.56
1896..	6	1	..	7	.884	63.25	7.82	6.13
1897..	5	3	1	9	.920	62.6	6.31	10.09
1898..	7	2	0	9	.898	66.3	3.45	11.60
1899..	5	..	2	7	.840	63.3	7.64	8.35
1900..	4	1	2	7	.888	62.8	6.86	10.47
1901..	9	..	3	12	.903	61.9	4.43	9.33
1902..	6	0	1	7	.908	62.6	3.56	5.04
1903..	7	2	2	11	.870	63.15	8.91	12.45
1904..	9	3	2	14	.900	61.8	9.18	11.16
1905..	5	5	2	12	.913	62.9	5.68	11.59
1906..	9	2	2	13	.885	63.0	5.13	16.00
1907..	5	3	5	13	.878	60.55	7.13	7.79
1908..	6	7	2	15	.900	64.5	5.66	12.15
1909..	9	4	0	13	.880	62.45	5.77	14.31
1910..	8	2	1	11	.909	63.6	5.27	

TABLE II.

DEPARTURES FROM THE MEAN.

Year.		Summer Pressures.	Summer Temperatures.	No. of Monsoonal Depressions.	Following Winter Rainfall.
		Av. Mean = 29·900	Av. Mean = 63·1	Mean = 11·3	Mean = 11·2
1888	..	+ .066	− 0.9	− 5.3	− 3.3
1889	..	+ .033	+ 1.6	− 0.3	+ 4.2
1890	..	+ .018	+ 2.6	+ 2.7	+ 3.1
1891	..	+ .040	− 1.0	− 1.3	− 1.0
1892	..	+ .002	− 0.3	+ 2.7	+ 2.4
1893	..	− .043	0.0	+ 3.7	+ 3.5
1894	..	− .018	+ 0.9	+ 3.7	+ 4.7
1895	..	+ .040	+ 1.4	− 1.3	− 3.6
1896	..	− .016	+ 0.2	− 4.3	− 5.0
1897	..	+ .020	− 0.5	− 2.3	− 1.1
1898	..	− .002	+ 3.1	− 2.3	+ 0.4
1899	..	− .060	+ 0.2	− 4.3	− 2.8
1900	..	− .012	− 0.3	− 4.3	− 0.7
1901	..	+ .003	− 1.2	+ 0.7	− 1.9
1902	..	+ .008	− 0.5	− 4.3	− 6.1
1903	..	− .030	+ 0.1	− 0.3	+ 1.3
1904	..	0	− 1.3	+ 2.7	0.0
1905	..	+ .013	− 0.2	+ 0.7	+ 0.4
1906	..	− .015	− 0.1	+ 1.7	+ 4.8
1907	..	− .022	− 2.5	+ 1.7	− 3.4
1908	..	− .000	+ 1.4	+ 3.7	+ 1.0
1909	..	− .020	− 0.6	+ 1.7	+ 3.1
1910	..	+ .009	+ 0.5	− 0.3	

In this table the average mean (normal) pressures and temperatures from which the departures are measured are obtained from all years available ; the means for the monsoonal depressions and rainfall are based upon the 20 years, 1889–1908 inclusive. The introduction of the years 1888 and 1909, which was made later, does not appreciably affect these values.

TABLE III.

Departures from the Mean.						Following Winter Rain Departures.
Years.		Monsoonal.	Barometric. × − 0·6	Temperature. × 1·4	Sum.	
1888	..	− 5.3	− 4.0	− 1.3	−10.6	− 3.3
1889	..	− 0.3	− 2.0	+ 2.2	− 0.1	+ 4.2
1890	..	+ 2.7	− 1.1	+ 3.6	+ 5.2	+ 3.1
1891	..	− 1.3	− 2.4	− 1.4	− 5.1	− 1.0
1892	..	+ 2.7	− 0.1	− 0.4	+ 2.2	+ 2.4
1893	..	+ 3.7	+ 2.6	− 0.0	+ 6.3	+ 3.5
1894	..	+ 3.7	+ 1.1	+ 1.3	+ 6.1	+ 4.7
1895	..	− 1.3	− 2.4	+ 2.0	− 1.7	− 3.6
1896	..	− 4.3	+ 1.0	+ 0.3	− 3.0	− 5.0
1897	..	− 2.3	− 1.2	− 0.7	− 4.2	− 1.1
1898	..	− 2.3	+ 0.1	+ 4.3	+ 2.1	+ 0.4
1899	..	− 4.3	+ 3.6	+ 0.3	− 0.4	− 2.8
1900	..	− 4.3	+ 0.7	− 0.4	− 4.0	− 0.7
1901	..	+ 0.7	− 0.2	− 1.7	− 1.2	− 1.9
1902	..	− 4.3	− 0.5	− 0.7	− 5.5	− 6.1
1903	..	− 0.3	+ 1.8	+ 0.1	+ 1.6	+ 1.3
1904	..	+ 2.7	+ 0.0	− 1.8	+ 0.9	0.0
1905	..	+ 0.7	− 0.8	− 0.3	− 0.4	+ 0.4
1906	..	+ 1.7	+ 0.9	− 0.1	+ 2.5	+ 4.8
1907	..	+ 1.7	+ 1.3	− 3.5	− 0.5	− 3.4
1908	..	+ 3.7	+ 0.0	+ 2.0	+ 5.7	+ 1.0
1909	..	+ 1.7	+ 1.2	− 0.8	+ 2.1	+ 3.1
1910	..	− 0.3	− 0.5	+ 0.7	− 0.1	

This table shows the series of results obtained by adding to the monsoonal departures those for pressure and temperature multiplied by the appropriate factors. These results are slightly more accordant in sign with the winter rains departures than are the monsoonal departures, but tend to numerical exaggeration. This is, of course, inevitable under this treatment when the three data are in agreement.

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[*] Since the above was written the mean rainfall for the Riverina District of New South Wales has been taken out in the same way as that for Northern Victoria, the stations selected being Balranald, Hay, Moulamein, Deniliquin, Kilnyana West, Corowa, Wagga Wagga, Yanko, Widgiewa, and Urana. As was anticipated the curve showing the departures from the mean for the 20 years, 1889 to 1908 inclusive, is very similar to the Victorian one.

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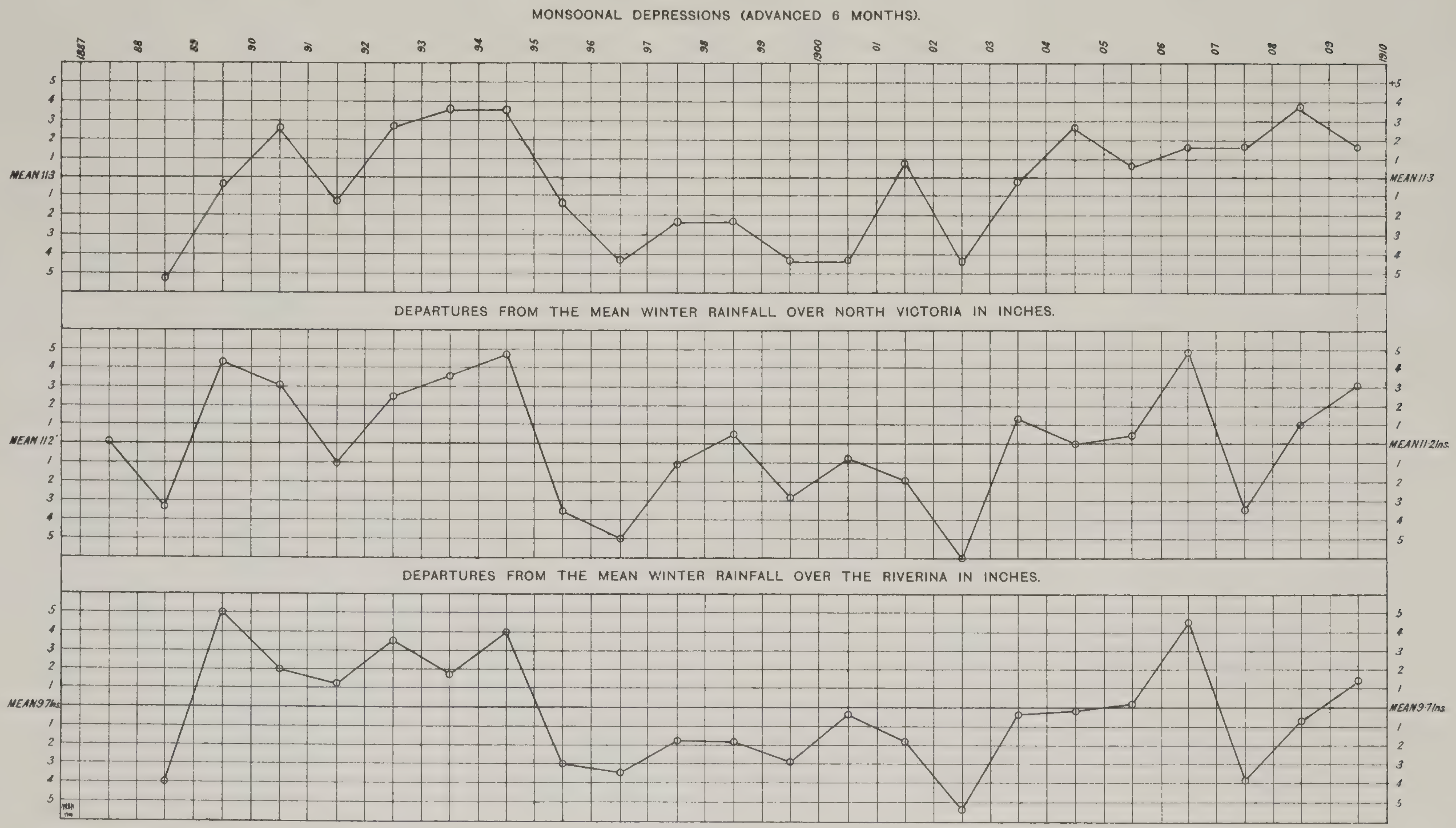
DIAGRAM showing the departures from the Mean Winter Rainfall over Northern Victoria and the Riverina and the corresponding departures from the mean number of Monsoonal depressions during the preceding summer (*i.e.* preceding half year).



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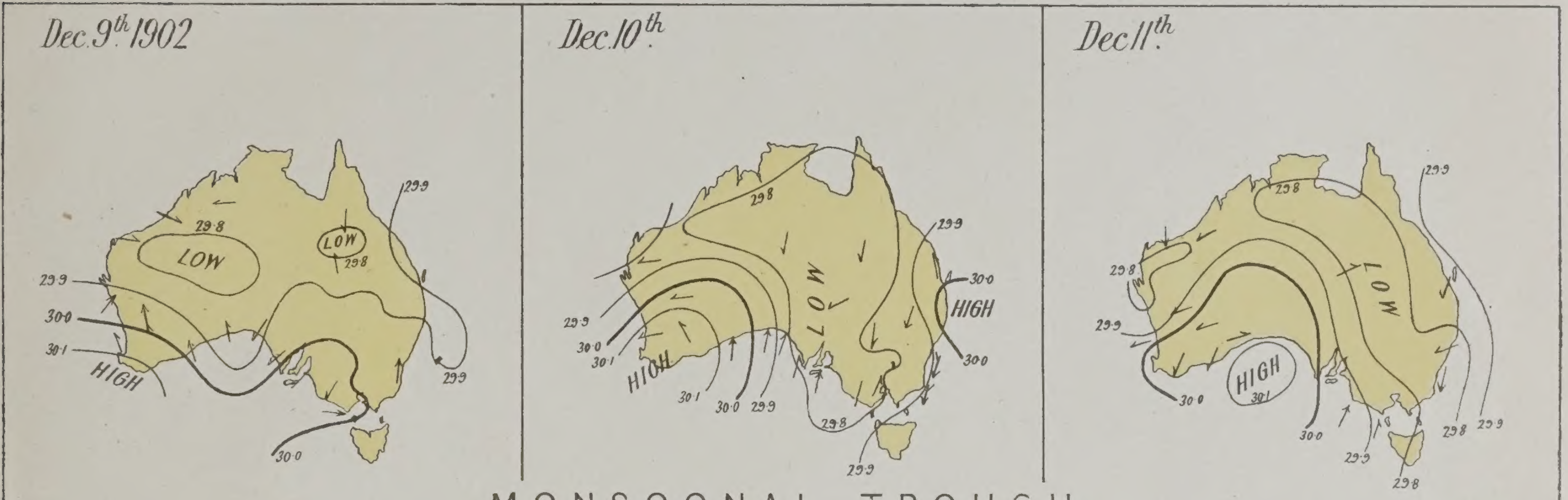
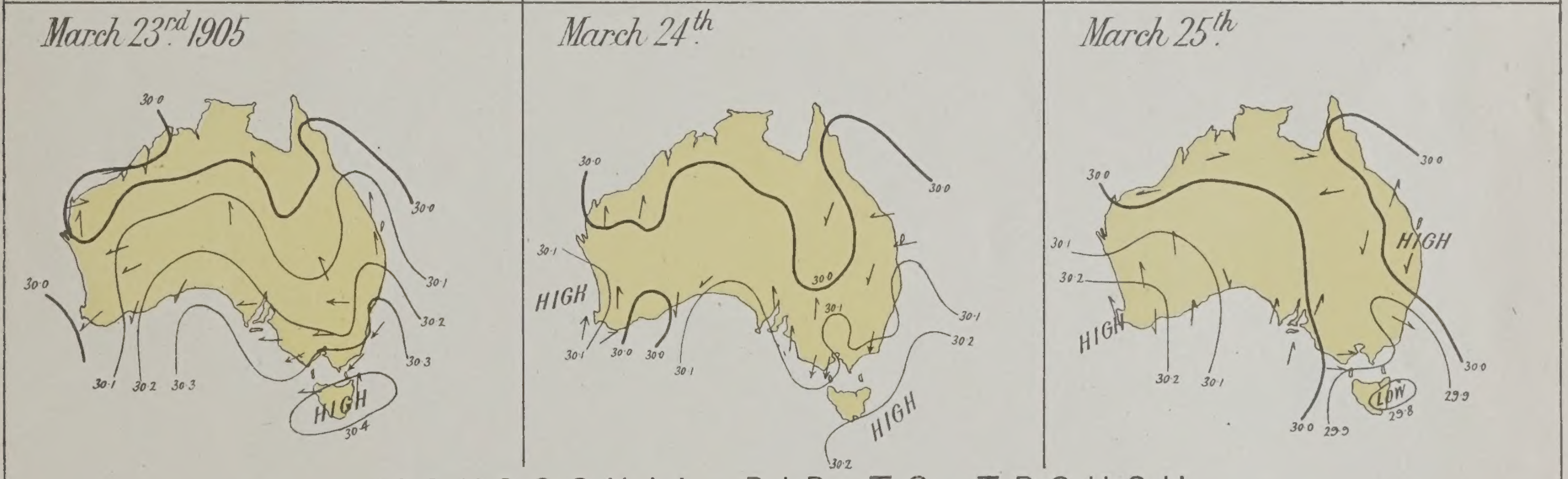
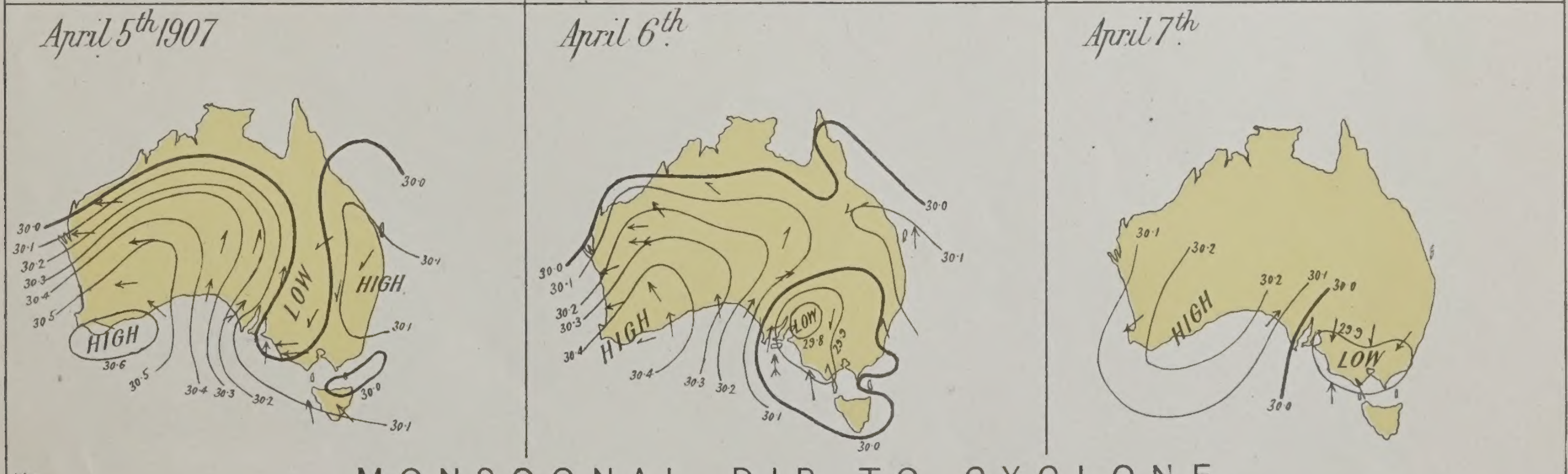
These are Isobaric representations of some fairly typical monsoonal depressions. They are not the best which could have been selected, but were chosen on account of their characteristic progress and development.



MONSOONAL TROUGH.



MONSOONAL DIP TO TROUGH.



MONSOONAL DIP TO CYCLONE.

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